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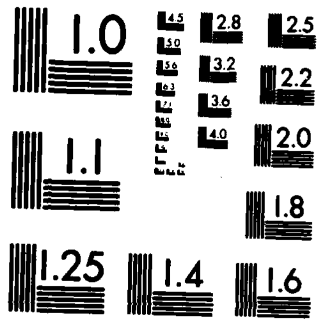

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Desert Emergency - Lack of Water - How to Find and Collect Water.

Plants and Human Survival in the Desert

The Principal Investigator and Contractor
Professor Yitzchak Gutterman

Contract Number: DAJA 45-83-C-0051
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Experiments indicate that during winter the highest yield of transpiratory water will be obtained from branches from the south-facing direction, covered with a thin plastic bag. There are no significant differences between wadi habitats. Retamn raetam is a suitable species, because the combination of deep and shallow roots reduces dependency on local rainfall.

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As we mentioned in the first periodical report, the focus during the first period was merely to collect transpiratory water from Retama raetam plants under desert conditions. The aims of the second part of this study were 1) to find out if there is, and if so, what is, the connection between the direction of the branches covered with the PVC bags and the amount of water collected in the bags, 2) to determine if plants from different habitats will have different yields during the same period of the year, 3) to see if we can improve the yield of transpiratory water by using colored bags (different wavelengths of light), 4) to be able to compare the yield of water which can be collected from different desert habitats during winter as compared to the same plants from these same habitats during summer, 5) to measure osmotic potential of the branches of the plants in the different directions from the different habitats as well as, 6) to make anatomical observations of these branches to determine whether or not there is a visible method by which one can choose, from among a group of plants, the plant that will give the highest yield of transpiratory water after being covered with PVC bags.

II. Plant Material:

The first important consideration was choosing the best plant for this study. It had to be a plants that: 1) does not secrete salt from it's leaves (otherwise the water collected will be salt water instead of distilled water), 2) has a deep as well as a shallow root system, 3) isn't poisonous, 4) doesn't have deciduous leaves, 5) inhabits different desert habitats and is relatively easy to find in fairly large numbers - at least in certain habitats in the desert area. The plant species which answers to all these requirements, moreso than any other plant, is Retama raetam.

Retama raetam plants 1) do not excrete salts, 2) have two different root systems: the deep system which can penetrate to depths greater than 15m in wadi beds, sand areas and other habitats to obtain water, as well as obtaining water from underground aquifers passing under at great depths. Therefore the plant does not need to depend on the local precipitation only, but rather has access to more permanent, relatively rich, source of water in the desert. The shallow root system enables the plant to utilize even the very light precipitation in the area, 3) aren't poisonous, 4) don't shed their leaves. This plant has very tiny leaves only for a short period of time and during most of the year, photosynthesis is carried out by the green branches which contain stomata along their depressions, 5) are among the few plants that are capable of inhabiting completely different habitats: a. along the Mediterranean seashore in the Mediterranean phytogeographic area where the plants occupy the zone of active dunes. This plant can survive under situations in which it is covered by sand, or the opposite, in which the plant and it's root system are exposed. Sometimes a sand dune of 2 or more meters will move through in a short time, yet the root system is able to remain anchored and provide water to the plant canopy b. areas of stabalized sand dunes, in which it is the dominant plant. These two abovementioned habitats occupy large areas along the Mediterranean seashore and the northern Sinai, c. inland sand areas in the Northern Negev and the Arava Valley, in which the plant is an important plant in different plant communities of stabalized sand dunes, d. wadi beds in all the big wadis on the Jordan Valley, the Judean Desert and the Negev and Sinai, in which the plant uses it's taproot for utilizing the water from the depths of the wadi bed year round, e. soil pockets between rocky slopes on the east facing slopes of the Judean and Samarian deserts.

From all the abovementioned, we found that it is important to study and concentrate on Retama raetam for the purpose of collecting transpiratory water from plants under desert conditions. The great advantage of our Desert Reserarch Institute is that we are situated in the middle of the Negev Desert Highlands, yet have laboratory equipment, water and electricity readily available to us. The wadi habitats neighboring the Institute can be broken down into a microscale of five different orders, each receiving differing amounts of water according to the distribution of precipitation and the nunber of floods/year in the main wadis. Orders I-IV are narrower, loess-covered wadis, while order V is wider and covered with gravel and stones. In years such as this one, in which rainfall occurances were sparse and quantities were low, order I (and sometimes II) receive more water than either IV or V. However, V still has more water available to the plants, because in this order the wadi bed is part of a wide wadi covered with gravel and the deep root system of the plants are able to tap water from the aquifer below which contains water accumulated from the previous year or even several years past. In a very good year, with a number of flood-quality rains, the amount of water available to the root systems in all wadi orders is much greater than in a lesser rainfall year with little or no flooding.

III. Materials and Methods:

1) In the first set of experiments, started on 26/12/83, 3 plants which grow naturally in a wadi (orders I-IV) near Sede Boqer were covered with transparent PVC bags, 60x50cm. Temperatures were 2°C-5°C during the night and 25°C-30°C during the day. The resulting water yields from these three plants are summarized in Table 1.

2) In the second set of experiments, started 13/2/84, 6 plants naturally inhabiting wadis (orders I-IV) near Sede Boqer and 6 artificially irrigated plants (comparable to order V), within Sede Boqer campus, were covered as in the first experiment, except with 120x80cm bags, to compare the water yield between the two groups. Temperature measurements in the PVC bags, were 0°C during the night (11-14° C on a cloudy night) and 25°C-38°C during the day. After measuring the transpiratory water from the covered branches, the branches were cut and dried and the dry matter of the green parts of the branches was weighed, in order to calculate the yield of water (ml) per gram of dry matter of the branches. The results are summarized in Table 2.

3) In the third set of experiments, plants were covered with two layers of transparent PVC bags, with colored cellophane paper between the layers, using blue, green, yellow, red and red+blue cellophane and a control with uncolored transparent cellophane. This preliminary study was to determine whether different wavelengths of light affect the water yield by affecting the stomatal openings.

4) Water potential of the plants from experiments 1 and 2 was measured using a pressure bomb, by means of gas pressure passing into the xylem tissue. At around noon, covered branches from both the south and north facing directions were measured with the pressure bomb, and results

compared. Comparisons were also made between branches from the past season and branches from a year ago, both with and without fruit, in both the south and north facing directions.
5) Samples of the branches measured with the pressure bomb were taken for anatomical study. Cross-sections were cut to look for differences in the tissues from different branches, to connect the yield of water from a branch in a certain direction, with osmotic potential and anatomical characteristics. 6) Measurements were taken of a. the amount of precipitation and distribution of rains, b. temperature within the plastic bags at both the upper and lower parts of the branches.

IV. Results:

The data from Experiment 1, which is summarized in Table 1, shows that there is a difference in water yield from branches from the same plants, oriented in different directions. During winter (Dec-Feb), the greatest amount of transpiratory water was collected from branches facing south - giving 37% of the total yield from the plant. In contrast, the north facing branches gave the lowest yield - only about 18% of the total. The western and eastern facing branches gave almost the same yields.

As can be seen in Table 2, the transpiratory water yield results in experiment 2 are the same as in experiment 1. In addition, the yield/500 g dry matter of green branches was also measured and these results are likewise summarized in Table 2. The average yield/500 g dry matter of south facing branches, from the 6 plants in their natural habitats, was 3130ml/ 500 g dry matter. The average of the north facing branches from the same 6 plants was only 242 ml/500 g dry matter. The results from the west and east facing branches were 278 and 259 ml/500 g dry matter, respectively. Very similar results were found from the artificially irrigated plants in the campus, in which the south facing branches averaged 308 ml/500 g dry matter. However, the east facing branches gave a much higher yield than those in their natural habitat - 378 ml/500 g dry matter compared to only 259 ml/500 g dry matter.

From experiment 3, in which we measured accumulation of water during the day compared to during the night, we have seen that during the dark period, when stomata are closed, there is no accumulation of transpiratory water. From the plants covered with plastic bags and different colors of cellophane paper, we have found that red light gives the best results and far-red light, the worst results with blue, green and yellow giving intermediate yields.

In experiment 4, the osmotic potential of branches of plants from experiments 1 and 2 was measured. Both branches with new growth from the winter and branches with fruit and flowers, but no new growth were measured. In addition, branches from south and north facing directions were also compared. There was very little difference between branches from this past year and branches from a year ago, either with or without fruit, as well as from both directions. All the measurements were in the range of -18 to -23 bars. The measurements of the artificially irrigated plants were also in the same range. The anatomical test results,from branches from the different directions,and from branches of the past season as well as last year, are now being analyzed.

Table 1: Water collected from Retama raetam from branches facing in south, north, west, east directions, covered with transparent PVC bags (60x50cm). Experiment started 26/12/83. Mean of evaporated water per bag per day and the total yield of water during the 12 days are summarized from three different plants (1,2,3) which grow naturally in a wadi near Sede Boqer.

* avg amount of water (ml) per day per bag

Direction / Plant #	South		North		West		East		Totals	
	total yield	avg*	total yield	avg*	total yield	avg*	total yield	avg*	total yield per plant	avg yield per plant
1	478.5	39.75	227.5	18.96	187	15.58	234	19.5	1127	93,9
2	724	60.3	312	26	543	45.25	312	26	1891	157.59
3	318.5	26.54	187	15.59	285	23.75	289	24.09	1079.5	89.96
avg/day		42.25		20.18		28.2		23.2		113.82
total yield	1521		726,5		1015		835		4097.5	
% of total	37.12		17.73		24.77		20.38		100	

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Table 2: Water collected from *Retama raetam* from branches facing in south, north, west, east direction, covered with transparent PVC bags 9120x180cm). Experiment started 13/2/84. Mean of evaporated water per bag per day and the total yield of water during the 4 days, as well as the calculation of water yield per 500 g dry matter from green branches per day are summarized from 12 different plants, 6 each from:A-Natural habitat around Sede Boqer and B-artificially irrigated plants in Sede Boqer Campus.

		South		North		West		East		Totals	
	Direction / Plant #	avg yield /day /bag	avg yield /day /500g dry matter	avg yield /day /bag	avg yield /day /500g dry matter	avg yield /day /bag	avg yield /day /500g dry matter	avg yield /day /bag	avg yield /day /500g dry matter	avg yield /day /bag	avg yield /day /500g dry matter
A	1	185	259	128.8	231	138	184.5	138.5	220	590.3	894.5
A	2	129.7	277	68.3	130.5	122.8	229	89.7	227	410.6	863.5
A	3	98.7	193	206.6	358.5	273.4	477	143.6	155.5	722.2	1184
A	4	206.3	337.5	112	137	(bag leakage)*		148.9	155	(467.1)*	(629.5)*
A	5	205.4	385.5	160.7	357	86	431.5	190	354	642.1	1528
A	6	164.6	431	142	240	97.1	167	238	443	641.7	1281
A	avg	164.9	313.8	136.4	242.3	(143.4)*	(297.8)*	158.1	259.1	(579)*	(1063.4)*
B	1	168	365	---	---	---	---	112	251	280	616
B	2	154	289.5	---	---	---	---	180.1	315	334.1	604.5
B	3	255	455.4	---	---	---	---	251	669.5	506	1125
B	4	83	136	---	---	---	---	196	341.5	279	477.5
B	5	120	327	---	---	---	---	120	276	240	603
B	6	183	273	---	---	---	---	266	417	449	690
B	avg	160.5	307.7	---	---	---	---	187.5	378.3	348	686

The first experiment was carried on during December, when after the long, hot summer, 4 rainy days gave a total of only 7.6 mm of rain. The rainfall during the second experiment was much greater - 42.8 mm from 9 rainy days. However, only 3 of the rains produced 4-14 mm , resulting in only 3 small floods in the wadis. The total rainfall through the end of March was 71.8 mm, with 29 mm of this total fell during 8 rainy days in March, as summarized in Table 3) These relatively late rains were less effective because of the relatively high temperatures and low air humidity.

Table 3: Distribution of rains during the rainy season, 1983/84; # of days of rain and # of floods

Month	# of rainy days	Monthly total in mm	# of floods produced
Dec	4	7.6	0
Jan	4	31.3	2
Feb	1	3.9	1
Mar	8	29.0	1
Total	17	71.8	4

As far as temperature is concerned, it seems that during winter, even if the maximum temperature (as measured with a max/min thermometer), reached a level of 40°C, there was no drastic tissue damage; the highest temperatures, over a long period of time, actually gave the highest yield from the branches in the south facing direction. The maximum temperatures in the plastic bags of the north, east and west directions were nearly the same, but the # of hours that the maximum temperature was maintained was less. This could be the reason why the water yield from these branches was less that from the south facing branches.

In experiment 3, in which colored cellophane paper was placed between a double layer of transparent PVC bags, the maximum temperature reached to more than 50°C and the tissue was damaged after a short time. This shows that it is quite important to use thin plastic bags to obtain water to prevent overheating and subsequent damage to the plant.

V. Conclusions

From all the experiments and measurements detailed above, it seems that during winter, the highest yield of transpiratory water, will be obtained from branches from the south facing direction, covered with a relatively thin plastic bag. As was seen from the yield of water and the osmotic potential of the plants, there are no big differences between the habitats from wadi order I to wadi order V. This is due to the sophisticated root systems of <u>Retama raetam</u> -

the shallow one, which utilizes water from even very light rainfalls, and the deep system, which can obtain water stored in the soil depths in the area, thus eliminating dependency on the rainfall in a particular area, during a particular season and year. It will be very important to repeat these experiments during the summer to be sure on this point and to find the way to get the highest yields under the high temperature and radiation conditions of the summer months.

These results, together with the results of a comparitive study of the anatomy of the branches of plants from different habitats, will lead us to the most important goal of this study - to be able to choose the right plant, and the right branches from that plant from among a population of plants, which will yield the greatest amount of transpiratory water, in the event that we have but one plastic bag in a life threatening situation.

This study, the methods we have developed and the knowledge we have acquired, will lead us into our second, most important subject - that of using plants as indicators of the presence of sweet ground water, near the soil surface, under desert conditions. From this study we will develop methods by which we can find fairly large amounts of drinking water in a relatively short amount of time, as compared with the small amounts of water yielded and the long amount of time necessary for collecting transpiratory water according to the first method.

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